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SOME ASPECTS OF MANAGING SECOND GROWTH WOODLANDS IN UPPER MICHIGAN

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TABLE OF CONTENTS

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Lake States Forest Experiment Station 1/

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By F. R. Longwood 2/

Most of the old-growth northern hardwood stands in the Lake States region have been clear cut and large areas of the remaining stands are rapidly being liquidated. A typical example is the west half of the Upper Peninsula of Michigan where more than half of the remaining old-growth hardwood stands were liquidated during the last 15 years. 3/ Consequently, the time is rapidly approaching when the second-growth hardwood stands in the northern part of the Lake States will become the major source of hardwood lumber, veneer, and other products for the region. About a quarter of the 7.2 million acres of second-growth hardwoods in the Lake States 3/ 4/ is in farm woodlands, generally not over 50 to 100 acres in extent. The proper management of these tracts would result in vast quantities of raw material for the region's wood-using industries as well as substantial returns to the farm owners.

Because of the importance of the farm woodland to the future economy of the area, a farm woodland study was installed in 1946 on the Upper Peninsula Experimental Forest near Dukes, Michigan. Two main objectives motivated the study: (1) to encourage the proper management of small woodlands by the demonstration of good marking principles, practical logging techniques, good utilization, and judicious marketing; and (2) to provide accurate information on volume growth and financial return from a second-growth hardwood stand. The results of the first five years of cutting are summarized in this paper.

1/ Maintained at University Farm, St. Paul, Minnesota, by the U. S. Department of Agriculture in cooperation with the University of Minnesota.

2/ Research Forester, U. S. Forest Service, Lake States Forest Experiment Station, Upper Peninsula Experimental Forest, Marquette, Michigan.

3/ Cunningham, R. N. Changes in forest conditions 1936-1949 North Central Minnesota and Upper Peninsula of Michigan (A preliminary analysis), Lake States Forest Exp. Sta., Sta. Paper No. 25, 20 pp. mimeo. July 1951.

4/ Cunningham, R. N., and Forest Survey Staff, Lake States Forest Exp. Sta. Forest resources of the Lake States region. U. S. Dept. Agr. Forest Resource Report No. 1, 57 pp., illus. 1950.

Description of the Stand

A 40-acre second-growth tract of average quality was selected as being representative of many farm-owned woodlands. It consisted of 30 acres of northern hardwoods, and 10 acres of ash-elm, a timber type which very frequently occurs on wet sites in mixture with northern hardwoods (figure 1). The area had been logged about 35 years previously, at which time the usual number of low-value trees were left.

The average acre in 1946 had 64 trees 10 inches and over in diameter and cruised 5,628 board feet (gross Scribner Dec. C rule).5/ Cull was about 27 percent of gross volume 6/, leaving a net scale of 4,100 board feet per acre. The average acre also had 157 trees 5 to 9 inches diameter, containing an additional volume of 10.4 cords. Tops of sawlog trees contained another 10.1 cords, making an over-all volume of more than 30 cords. Basal area averaged about 122.7 square feet per acre. The stand was well stocked but was low in merchantable quality because of the predominance of small trees below 14 inches and heavy cull in larger trees.

Growth

Calculated annual growth 7/ for the next 5-year period (1946-1950) was 212 board feet gross (155 board feet, net) per acre in trees 9.6 inches and over or 8,480 board feet gross (6,200 board feet net Scribner) for the tract. However, checks at the end of the five-year period showed that this should have been 126 board feet gross or 5,040 board feet for the tract.

Trees 4.6 to 9.5 inches in diameter were expected to produce another 9.8 cubic feet of wood per acre annually. The initial cutting plan called for the removal of a volume equivalent to the total gross growth during the first 5-year period of management.

5/ By Forest Survey standards (measuring all hardwood trees 12 inches and larger by International $\frac{1}{4}$-inch rule) the cruise would have been slightly higher. The overrun of International over Scribner (about 15%) more than offsets the elimination of 10 and 11-inch trees.

6/ Zillgitt, W. M., and Gevorkiantz, S. R. Estimating cull in northern hardwoods. Lake States Forest Exp. Sta., Sta. Paper No. 3. 7 pp., mimeo. November 1946.

7/ Gevorkiantz, S. R., and Duerr, W. A. Methods of predicting growth of forest stands. Lake States Forest Exp. Sta., Economic Note No. 9, 59 pp. mult. April 1938.

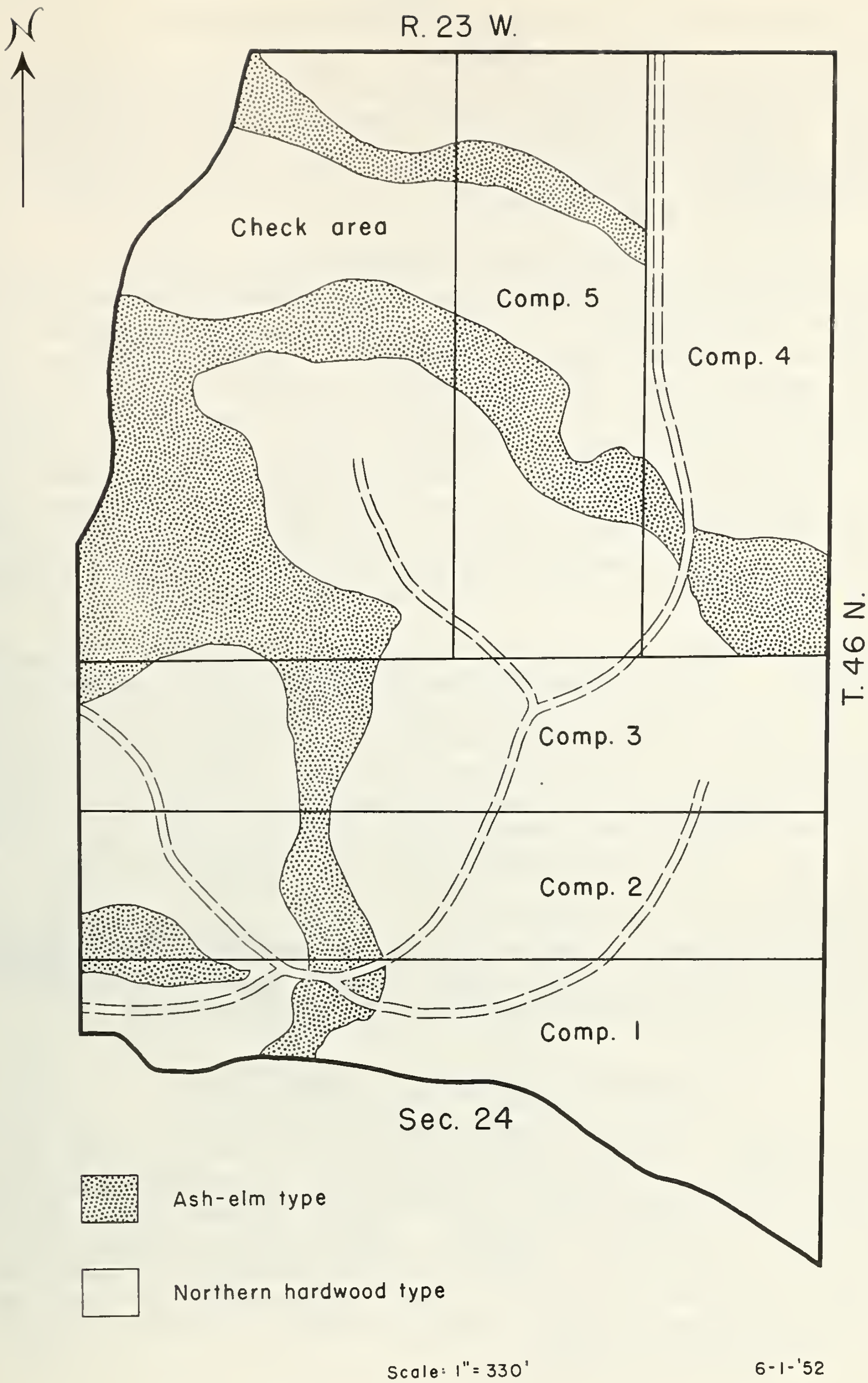

Figure 1. Farm woodland study area, Upper Peninsula Experimental Forest, Marquette, Michigan.

Cutting

The 40-acre tract was divided into five compartments of eight acres each. One of these compartments has been cut over each year during the five years since the study was established, removing annually the equivalent of the estimated annual growth on the entire 40 acres. Thus, the entire area was cut over during the five-year period, but each year's cutting operations were concentrated on only eight acres.

The aim during the first 5-year period was to cut annually the estimated growth of 212 board feet gross per acre in trees 9.6 inches in diameter and larger, plus 9.8 cubic feet (0.14 cord) per acre in smaller trees. This amounted to an anticipated annual cut of 8,480 board feet, gross scale, of sawlogs, plus 392 cubic feet (5.6 cords) of cordwood from trees in the smaller diameters. In addition, tops of sawlog trees were expected to yield another 12.4 cords per year, and some additional volume was expected from the salvage of dead trees. Cutting followed this pattern very closely. However, the initial cuttings removed the most defective trees, resulting in a relatively small net volume of merchantable sawlogs and a correspondingly large volume of chemical bolts (cull logs 7 to 9 feet long) and chemical wood (4-foot wood from tops and small trees).

All logging was done by local residents using conventional farm-owned tools and equipment. One- and two-man crosscut saws were generally used for felling and bucking. Horses or small farm tractors were used for skidding and for loading. Cutting was concentrated in the larger trees and trees of poor form and quality in all size classes with only a few trees below five inches in diameter being cut. In order to reduce the cull in the stand, particular attention was given to the removal of trees having poor form or containing excessive rot. Cull trees suitable only for chemical wood were also harvested.

All marked trees were cut regardless of size or quality and converted into logs, softwood pulpwood, chemical bolts, or cordwood. Utilization was down to a 4-inch top or less. The logging job was generally very satisfactory each year with only moderate damage to the residual stand.

Products Harvested and Annual Return

The total volume of products harvested and sold per acre over the 5-year period amounted to 343 board feet, net scale, of sawlogs, 1.42 cords (4x4x8 feet) of chemical bolts, 1.16 cords of chemical wood, and 1.00 cord of spruce and fir pulpwood (table 1). Some 1,060 board feet, gross scale, of sawlog-size material was actually cut according to the plan, but the heavy cull (68 percent) in the cut trees, principally in the large defective trees left during the previous logging, accounts for the relatively small volume of merchantable sawlogs.

Net roadside value of all products over the 5-year period varied from $249.16 in 1947 to $382.32 in 1950, averaging slightly over $300.00 per year for the 5-year period (table 2). Total roadside value of all products sold amounted to $1,520.16. The cost of a single horse, team, or tractor

Table 1.--Products harvested from the farm woodland over a 5-year period

Year	Annual net volume cut by products			
	Sawlogs	Chemical bolts 1/	Chemical wood 2/	Pulpwood
	Board Feet	Cords	Cords	Cords
1946	4,350	13.2	6.3	3.4
1947	3,120	10.0	5.5	9.6
1948	1,160	5.7	20.2	6.4
1949	3,940	11.3	8.6	8.8
1950	1,135	16.6	6.0	11.7
5-year total	13,705	56.8	46.6	39.9
Average 3/ per acre	4/ 343	1.42	1.16	1.0

1/ Cull logs 7-9 feet long and 9 inches d.i.b. or larger from main stem and tops.

2/ Material 4 feet long and 3-8 inches d.i.b. from tops and small trees.

3/ Average volume per acre harvested during the 5-year cutting cycle.

4/ Cut trees averaged 68 percent cull.

Table 2.--Annual returns from the farm woodland over a 5-year period

Year	Gross value of products 1/	Equipment costs 2/	Net roadside value of products	Time worked	Returns per man-hour 1/
	Dollars	Dollars	Dollars	Hours	Dollars
1946	313.73	59.40	254.33	208	1.22
1947	317.76	68.60	249.16	227	1.10
1948	323.87	27.00	296.87	220	1.35
1949	367.48	30.00	337.48	281	1.20
1950	407.10	24.78	382.32	251	1.52
Total for 5 years	1,729.94	209.78	1,520.16	1,187	-
Average per year	345.99	41.96	304.03	237.4	1.28

1/ Includes stumpage value averaging $26.85 per year, contributing about $0.11 per man-hour.

2/ Includes either tractor or horse rental annually. Teamster also hired in 1946, 1947, and 1948.

for skidding has been deducted from the gross roadside value, as this is an item of cost to the operator, even though his own team or equipment may be used.

The net roadside value of all products is considered to be the net return for the effort expended by the operator. Stumpage, amounting to an average of $26.85 per year, is included in the returns per man-hour, as it is doubtful if this small quantity of highly defective material could have been marketed under normal conditions. The returns varied from $1.10 per man-hour in 1947 to $1.52 per man-hour in 1950, averaging $1.28 per man-hour for the 1,187 hours of work provided by the five annual cuts.8/

Interest on the investment and taxes on the property were not considered in computing the annual returns per man-hour. Calculations indicate that these are being more than offset by the increases in timber value on the land.

The 40-acre tract five years ago had a market value of about $20 per acre, mostly in stumpage value at $5 per M. Today, it is worth considerably more. At maturity, perhaps 100 years of age, stumpage then mostly in large well-formed trees should be worth $30 or more per M. Over a 65-year period, this would mean an average gain of $0.385 per M, or about $2 per acre per year.

Interest on the investment, assuming 5 percent of $800 for the tract, would amount to $40 annually, or $1 per acre. Taxes on land of this kind run about $5 per forty, or $0.125 per acre annually. Thus, annual charges appear to be fully covered by accretions in property value.

It is interesting to note that approximately six hours labor were provided annually by each acre of timber. On this basis, approximately 350 acres of second-growth timber would provide one man-year of labor at an annual return of $7.50 per acre including stumpage, or $2,625 per year on the 350 acres.9/ It is reasonable to assume that the return per acre and per hour of woods work will be increased as this farm woodland or any other second-growth stand is placed under more intensive management. Repeated cuttings and the resulting increase in value and size of the trees harvested, due to good management, will result in an increasing proportion of the operator's time being spent in the harvesting of high-value products. Low-value products, such as chemical wood and bolts and small low-quality sawlogs, show a much smaller return per man-hour than such products as veneer logs, good quality sawlogs, and other high-value material. Under good management, a farm woodland or any other second-growth hardwood stand will provide a

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8/ The second 5-year cutting cycle was begun in 1951 when Compartment 1 was recut to leave a basal area of slightly under 90 square feet per acre in trees 2 inches d.b.h. and over. A net income of $2.44 per hour, including stumpage, was realized for the 320 hours of labor involved in cutting the 8-acre compartment. The heavier cut, use of a one-man power saw, and good market conditions were largely responsible for the increased rate of return to labor. Stumpage was valued at $44.55, making up approximately $0.14 per hour of the hourly income.

9/ On the basis of the 1951 returns when a heavier cut was made, 350 acres of similar second-growth would provide about 1.3 man-years of labor annually with a return of $19.52 per acre, or better than $6,800 per year, including stumpage valued at $388.50.

series of annual or periodic cuttings of material that should be of progressively higher value.

Volume Growth

It is customary in this locality to list volumes in board feet for trees 9.6 inches and over in diameter and trees 4.6 inches to 9.5 inches in diameter in cubic feet or cords. To simplify both the management procedures and analysis of the results, all volumes shown in this report, whether in cubic feet, board feet, or square feet of basal area 10/, have been computed for all trees.

Cubic Feet

The average annual gross cubic foot growth per acre has varied from 34.72 cubic feet (0.50 cord) on Compartment No. 2 to 114.01 cubic feet (1.63 cords) on Compartment No. 1. The average for the entire area was 67.91 cubic feet (0.97 cord) (table 3). 11/

On the basis of an average annual growth of 67.91 cubic feet (0.97 cord), the 5-year cut should have amounted to 339.55 cubic feet (4.85 cords) per acre. However, 431.13 cubic feet (6.16 cords) per acre were removed during the 5-year period, thereby reducing the stand volume some 91.58 cubic feet (1.31 cords) per acre (table 3). This is a heavier cut than originally planned, but from all appearances this has not depreciated but has actually enhanced the growing conditions of the stand. Reproduction, or saplings, have not appeared in any appreciable number, indicating the stand is still heavily stocked and possibly overstocked to the point that all openings created by cutting are immediately filled in by crowns of trees competing in the overstory. This reduces new growth to a minimum.

Growth on a similar uncut check area has amounted to slightly over 69 cubic feet (0.99 cord) per year, which is one cubic foot more than the cut portion of the farm woodlot. However, the cut area has an advantage in growth over the uncut check, in that the increment, although approximately equal in volume, has occurred on fewer and better trees.

Basal Area

Total basal area increase in trees 2 inches in diameter and larger has amounted to slightly more than 1.1 square feet per acre annually (table 4). However, mortality losses in the 2-, 3-, and 4-inch diameter classes amounted to approximately 1.2 square feet annually, as a result of the very heavy stocking in small trees plus a small amount of logging damage. Consequently, it is evident that trees five inches and larger actually grew at the rate of 2.3 square feet of basal area annually per acre, half of this being lost through mortality in the 2-, 3-, and 4-inch tree classes.

10/ A measurement in square feet of the cross-sectional area of trees at a point 4½ feet above the ground.

11/ On the basis of 70 cubic feet per cord.

Table 3.--Gross cubic-foot volume and growth per acre by compartments 1/

Compartment number	Year cut	Original volume 1946	Cut 2/ volume	Volume 1950	Annual growth	
		Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cords 3/
1	1946	2,441.58	413.01	2,598.60	114.01	1.63
2	1947	3,071.70	437.08	2,808.20	34.72	0.50
3	1948	3,399.70	407.89	3,395.75	80.79	1.15
4	1949	2,836.80	459.91	2,572.70	39.16	0.56
5	1950	2,580.80	437.75	2,497.50	70.89	1.01
All		2,866.12	431.13	2,774.55	67.91	0.97
Check 4/		3,055.50	-	3,333.24	69.44	0.99

1/ Based on trees 4.6 inches d.b.h. and over on 8 1/10-acre sample plots per compartment and on 10 1/10-acre check plots.

2/ From 100-percent tally of trees marked for cutting.

3/ Based on 70 cubic feet, gross, per cord, excluding bark. Includes growth harvested in cut trees.

4/ Original measurement in 1947. Four growing seasons.

Table 4.--Gross basal area per acre before cutting, removed in cutting, and five years later
(Square feet)

D.b.h. class	Before cutting 1946	Cut trees 1946-1950	Present stand 1950
2	4.50	.00	2.54
3	7.60	.00	4.96
4	8.09	.00	6.85
5	8.98	.10	7.99
6	6.94	.19	8.18
7	6.48	.37	6.01
8	5.88	.59	7.07
9	6.54	.72	6.63
Sub-total	55.01	1.97	50.23
10	6.68	.93	5.72
11	7.76	1.09	6.93
12	5.30	1.08	6.67
13	6.68	1.11	4.84
14	6.15	1.05	6.15
15	7.36	1.08	6.14
16	4.89	.77	6.28
17	3.94	.71	2.76
18	3.53	.88	3.53
19	4.43	.69	3.94
20	2.73	.48	4.36
21	4.21	.72	3.01
22	1.32	.40	1.32
23	.72	.29	.72
24	.00	.16	.79
25	.85	.07	.00
26	.00	.07	.92
27	.00	.20	.00
28	.00	.00	.00
29	1.15	.09	.00
30	.00	.10	.00
Sub-total	67.70	11.97	64.08
TOTAL	122.71	13.94	114.31

As a comparison, annual basal area growth on two 20-year-old 12-inch diameter limit cuttings on the Upper Peninsula Experimental Forest at Dukes, Michigan, has averaged 3.475 square feet per acre over the past 20-year period, as compared to 3.423 square feet growth on two clear-cut plots at Dukes over the same period. A number of partially cut sawlog-size hardwood stands at Dukes have generally added basal area at a rate of 2.0 to 2.5 square feet annually.

Before cutting, the tract contained 122.7 square feet of basal area per acre in trees 2 inches and over (table 4). During the first cutting cycle, 13.9 square feet of basal area were removed, leaving an average of 108.8 square feet per acre. This is a rather heavy stocking, particularly in the smaller diameter classes.

Board Feet

Actual growth on the cut compartments has averaged 126 board feet annually over the 5-year period, compared to 146 board feet annually on the uncut check area over a 4-year period (table 5). Board-foot growth on the check area probably was larger because it originally had some 719 board feet more per acre in sawlog trees than the average for the five compartments before cutting, and 1,747 board feet more than the compartments after they were cut. The greater number of sawlog-size trees allowed a larger volume of board-foot growth to occur on the check area.

The actual board-foot growth was considerably below the estimated growth (126 compared to 212), resulting in an overcut of 430 board feet per acre during the 5-year period. However, most of the overcut came from cull trees, or very low-value logging remnants.

Table 5.--Original gross volume, cut volume, present volume and growth
(Board feet, Scribner rule)

Area	Gross volume per acre 1/			
	Original 1946	Cut 1946-1950	Present 1950	Annual growth
Cut compartments	5,628	1,077	5,183	126
Check area 2/	6,347	0	6,930	146

1/ Trees 9.6 inches d.b.h. and over.
2/ Original measurements made in 1947. Four growing seasons.

Diameter Growth

Average diameter growth of all species combined over the 5-year period did not vary appreciably over the five compartments that were cut. Residual trees in Compartments 2 and 5 showed the most rapid rate of diameter growth of 0.84 and 0.85 inch, respectively, in trees 9.6 inches and larger, compared to a low of 0.63 inch on Compartment 3 (table 6). The average diameter growth over the 5-year period on all compartments amounted to 0.76 inch, while trees on the check area grew at the rate of 0.48 inch over the 4-year period of measurement. Cutting apparently increased the average diameter growth by approximately 58 percent, thereby reducing the time to grow trees to merchantable size or economic maturity. This is the most desirable benefit resulting from improvement cuttings. However, it is likely that if the stocking were reduced to around 90 square feet, or lower, the diameter growth would be increased still more without any loss of total cubic-foot growth.

Table 6.--Average diameter growth, mortality, and ingrowth in trees 9.6 inches d.b.h. and over by compartments over a 5-year period

Unit	Average diameter growth, 5-year period	Annual Gross: Mortality per acre		Ingrowth per acre		Ingrowth less mortality	
	Inches	Board feet	Cubic feet	Board feet	Cubic feet	Board feet	Cubic feet
Comp. 1	0.70	0	0	26	27.2	26	27.2
Comp. 2	0.84	39	14.6	49	50.8	10	36.2
Comp. 3	0.63	0	0	7	7.5	7	7.5
Comp. 4	0.77	41	19.5	23	26.2	-18	6.7
Comp. 5	0.85	0	0	27	27.2	27	27.2
All compartments	0.76	16	6.8	26	27.8	10	21.0
Check 1/	0.48	47	18.2	7	7.5	-40	-10.7

1/ For a 4-year period only.

Mortality and Ingrowth

Annual mortality per acre in sawlog trees was three times greater in the uncut check area than in the cut compartments. An average of 16 board feet, or 6.8 cubic feet (0.10 cords), were lost per acre annually by mortality in trees 9.6 inches in diameter and larger on the cut areas, as compared to 47 board feet or 18.2 cubic feet (0.26 cords) on the check area (table 6). It can be assumed that this reduction in mortality was largely the result of harvesting trees about to die.

Ingrowth of trees into the sawlog class averaged 26 board feet or 27.8 cubic feet (0.40 cord) annually on the cut compartments, as compared to 7 board feet or 7.5 cubic feet (0.11 cord) annually on the uncut check area (table 6). Ingrowth minus mortality showed an average net gain of 10 board feet or 21.0 cubic feet (0.30 cord) on the five cut compartments compared to a loss of 40 board feet or 10.7 cubic feet (0.15 cord) annually on the check area. The small volume of ingrowth and the high mortality rate in the check area further demonstrates the practicability of improvement cuttings in second-growth stands.

Changes in Stand Structure

There has not been any appreciable change in the size-class distribution during the 5-year period, except in the 2-, 3-, and 4-inch diameter class. Some 157 trees per acre were tallied in the 4.6 to 9.5 inch diameter group at the initial measurement (table 7). About 6 trees per acre were cut in this size group, leaving a residual stand of 151 trees per acre. By 1950, ingrowth had increased this total to approximately 158 trees per acre, within one tree of the original stand.

There were 64 trees per acre of sawlog size before cutting; about 11 were cut per acre, leaving a residual stand of nearly 54 trees per acre. At the end of the 5-year cutting cycle, ingrowth had brought the sawlog stand back up to 60 trees per acre, approximately 4 trees below the number in the original stand. However, the stand was improved to some degree through the removal of some of the largest low-value logging remnants 24 inches in diameter and larger (table 7).

The average diameter of all trees in the stand 2 inches d.b.h. and over increased from 5.8 to 6.4 inches over the 5-year period. This change was influenced somewhat by the loss of 157 2-, 3-, and 4-inch trees per acre, due to severe competition, but not as a result of cutting.

It is clearly evident that cutting has not been sufficiently heavy to introduce reproduction or to prevent the death of small saplings due to severe competition (table 8). There were approximately 452 trees 2, 3, and 4 inches in diameter in 1946, and only 295 in 1950, a reduction of about 157 trees per acre. Only a minor part of this loss can be attributed to logging damage, as field observations indicate that the bulk of it is the result of suppression. This is considered a natural course of events in second-growth stands that are not opened up sufficiently to

Table 7.--Trees per acre by diameter classes before cutting and at the end of the 5-year cutting cycle
(Number of trees)

D.b.h. class	Before cutting 1946	Cut trees 1946-1950	Present stand 1950
5	66.00	0.70	58.75
6	35.40	0.95	41.75
7	24.25	1.40	22.50
8	16.85	1.70	20.25
9	14.80	1.62	15.00
Sub-total	157.30	6.37	158.25
10	12.25	1.70	10.50
11	11.75	1.65	10.50
12	6.75	1.38	8.50
13	7.25	1.20	5.25
14	5.75	0.98	5.75
15	6.00	0.88	5.00
16	3.50	0.55	4.50
17	2.50	0.45	1.75
18	2.00	0.50	2.00
19	2.25	0.35	2.00
20	1.25	0.22	1.75
21	1.75	0.30	1.25
22	0.50	0.15	0.50
23	0.25	0.10	0.25
24		0.05	0.25
25	0.25	0.02	
26		0.02	0.25
27		0.05	
28			
29	0.25	0.02	
30		0.02	
Sub-total	64.25	10.59	60.00
TOTAL	221.55	16.96	218.25

encourage new trees or to permit smaller stems to remain in the stand. Until this condition has been altered, no progress will be made towards the objective of changing this essentially even-aged second-growth woodlot to an uneven-aged stand. If a cut is to be made each year, it will be necessary gradually to get a better distribution of age and size classes. If this is not accomplished, there may be periods when it will not be profitable or advisable to make annual cuts.

Table 8.--Trees per acre below 4.6 inches d.b.h. in 1946 and in 1950 1/
(Number of trees)

D.b.h. class (Inches)	Before cutting 1946 2/	Present stand 1950
2	204.50	115.25
3	155.00	101.25
4	93.00	78.75
Total	452.50	295.25

1/ Based on 40 1/10-acre sample plots.
2/ None marked for cutting.

Cutting during next Five-Year Cutting Cycle

It is apparent that the initial cut over the five compartments has not been sufficiently heavy to materially reduce the cull in sawlog-size trees or to prevent the death of many sapling and pole-size trees. Both diameter and volume growth have been fairly rapid, but can be improved considerably by the removal of additional low-value and defective trees.

Cutting during the second five years of operation will be conducted on the same basis as before, except that the stand will be marked to leave a residual volume of 85 to 90 square feet of basal area per acre in trees 2 inches and over. This heavier cut should improve the over-all quality of the stand and, at the same time, provide a still greater return for stumpage and to the labor involved in logging. Total growth may not be increased appreciably. However, as a result of the lessened competition and reduced cull in the stand, a greater proportion of the total growth should become available as merchantable products at an earlier date. Ultimately this should increase the net returns from the woodland.

Summary

A 40-acre tract of 35-year-old northern hardwoods was placed under management on the Upper Peninsula Experimental Forest in northern Michigan to demonstrate good farm woodland management and to provide information on growth and economic returns.

The estimated annual growth on the entire 40 acres was cut from one-fifth of the area each year, thereby covering the entire area in the first 5-year cutting cycle. Detailed cost, return and growth records were maintained.

Cutting during the 5-year period removed a total of 343 board feet, net scale, of sawlogs, 2.6 cords of chemical wood and bolts, and 1.0 cords of pulpwood per acre. The total net roadside value of these products was $1,520.16 after equipment costs were paid. This gave an average return to labor of $1.28 per hour for the 237 hours of labor involved in the average year. Stumpage valued at $26.85 per year is included in these returns, amounting to about $0.11 per man-hour. It is doubtful if this small amount of low-value stumpage could have been sold on the open market. Returns per man-hour are expected to increase as the stand is improved by cutting. The value of the property is calculated to be increasing at an average rate of $0.875 per acre annually, after accounting for $1.125 per acre annually for taxes and interest.

The over-all quality of the stand was improved by the first series of cuts, but neither board-foot nor cubic-foot growth has been accelerated. Growth averaged about 126 board feet annually per acre, or approximately 1.0 cord (70 cubic feet) per acre annually in trees 4.6 inches d.b.h. and over. The distribution of trees by size classes has not been appreciably changed by cutting except for the removal of some large decadent logging remnants and the natural mortality in 2-, 3-, and 4-inch trees due to the heavy residual

stocking. The average stand diameter was increased by 0.6 inch over the 5-year period. Mortality in sawlog-size trees was reduced about two-thirds by the cutting. Ingrowth into the sawlog class was four times greater on the cut areas than in the uncut check plot.

It is apparent that the cutting which removed only 14 square feet of the original 123 square feet of basal area per acre was not heavy enough. The stocking should be gradually reduced to less than 100 square feet per acre in order to accelerate the rate of growth of residual trees and thereby reduce the number of years to economic maturity. Something between 85 and 90 square feet per acre is suggested as a desirable stocking for this stand in trees 2 inches and over.

Station Papers, 1946-53

Number

*1 Revised forest statistics for the Lake States, 1945, by the Forest Survey Staff, R. N. Cunningham, Regional Director. Sept. 1946.

*2 Postwar problems of the cross tie industry in the Lake States, by Arthur G. Horn and Harold F. Scholz. Sept. 1946.

3 Estimating call in northern hardwoods, by W. M. Zillgitt and S. R. Gevorkiantz. Nov. 1946.

4 The reforestation job in the Lake States - a new estimate, by Paul O. Rudolf. Nov. 1946.

5 Lake States forests and the pulp and paper industry, by E. L. Demmon. Dec. 1946.

6 Some forest-wildlife problems in the Lake States, by Shaler E. Aldous. Jan. 1947.

7 Growth and yield of jack pine in the Lake States, by S. R. Gevorkiantz. May 1947.

*8 Spacing of young red pine, by F. H. Eyre and Paul J. Zehngraff. June 1947.

*9 How can research help the Michigan timber owner? by E. L. Demmon. June 1947.

10 Optimum economic stocking for northern hardwoods, by W. M. Zillgitt. March 1948.

11 Balsam fir seed - its characteristics and germination, by Eugene I. Roe. March 1948.

12 An improved increment-core method for predicting growth of forest stands, by S. R. Gevorkiantz and Lucille P. Olson. July 1948.

13 Forestry situation in the Lake States, by E. L. Demmon. Sept. 1948.

14 Hybrid poplar planting in the Lake States, by Paul O. Rudolf. Dec. 1948.

15 Publications of the Lake States Forest Experiment Station, 1923-1948, by the Lake States Forest Experiment Station. Jan. 1949. Supplement No. 1, Dec. 1951.

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16 Forest fire burning conditions in the Lake States, by John S. Crosby. March 1949.

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20 Commodity drain from forests of the Lake States, 1948, by Arthur G. Horn. April 1950.

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25 Changes in forest conditions 1936-1949 north central Minnesota and Upper Peninsula of Michigan (A preliminary analysis), by R. N. Cunningham. July 1951.

26 Quality of logs and lumber obtained from an improvement cut in second-growth hardwoods in northern Wisconsin, by Carl Arbogast, Jr. Dec. 1951.

27 Reproduction on cut-over swamplands in the Upper Peninsula of Michigan, by Zigmond A. Zasada. Dec. 1952.

28 Burning index ratings in fire control planning, by J. A. Mitchell. Nov. 1953.

29 Some aspects of managing second-growth woodlands in upper Michigan, by F. R. Longwood. Dec. 1953.